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FOR
CMOS IMAGE SENSOR HAVING DOUBLE GATE INSULATOR THEREIN AND
METHOD FOR MANUFACTURING THE SAME

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CMOS IMAGE SENSOR HAVING DOUBLE GATE INSULATOR THEREIN
AND METHOD FOR MANUFACTURING THE SAME

Field of the Invention

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The present invention relates to a method for manufacturing a semiconductor device; and, more particularly, to a method for manufacturing a complementary metal oxide semiconductor (CMOS) image sensor having a double gate insulator in a pixel array with an enhanced optical property and an electrical property.

Description of the Prior Art

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As is well known, a photodiode image sensor device is the most commonly used a device for detecting images. A typical photodiode image sensor device comprises a reset transistor and a light sensor region formed by a photodiode. For example, a photodiode is formed with an n-type doped region and a p-type substrate. When the photodiode image sensor is in operation, a voltage is applied to the reset transistor gate to turn on the reset transistor and to charge the N/P diode junction capacitor. The reset transistor is turned off when the charging of the N/P diode junction capacitor has reached a certain high voltage. The N/P diode generates a reverse bias to form a depletion region. When a light is projected on the N/P diode light sensor, electrons and holes

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are generated. These holes and electrons are separated by the electrical field of the depletion region, causing the electrons to travel in the direction of the N-type doped region to lower the voltage of the N-type doped region, whereas the holes travel in the direction of the P-type substrate.

A charge coupled device (CCD) image sensor has a high dynamic range and a low dark current. The sophistication of the current technology of the CCD image sensor allows the CCD image sensor to become the most popular image sensing device. The manufacturing for the CCD image sensor is, however, rather special. The price of the CCD image sensor is therefore very high. Moreover, the driver requires a high voltage operation, leading to problems of high power dissipation and inability of random access of memory.

Meanwhile, a complementary metal oxide semiconductor (CMOS) image sensor has the characteristics of high quantum efficiency, low read noise, high dynamic range and random access. The CMOS image sensor can combine with other control circuit, A/D converter and several signal processing circuits on a single wafer to achieve the so-called system on a chip (SOC). The progress of the technology of a CMOS image sensor, therefore, greatly reduces the cost of an image sensor device, the picture size and the power of dissipation. The CMOS image sensor is therefore recently replacing the CCD image sensor.

Referring to Fig. 1, there is provided a cross sectional view of a conventional CMOS image sensor including a

semiconductor substrate 110, a p-type epitaxial layer 112, a pixel array 101, a logic circuit 102 and field oxide (FOX) regions. Herein, the p-type epitaxial layer 112 is formed by epitaxially growing up an upper portion of the p-type semiconductor substrate 110. The pixel array 101 and the logic circuit 102 are isolated from each other by forming the FOX region therebetween.

In the pixel array 101, a p-well 114 is formed in a predetermined location of the p-type epitaxial layer 112 of the pixel array 101, where a drive transistor (Dx) and a select transistor (Sx) are formed in a post fabrication process. In the other predetermined location of the p-type epitaxial layer 112 in the pixel array 101, there is formed a buried photodiode (BPD), where a transfer transistor (Tx) and a reset transistor (Rx) are formed by a post fabrication process. Herein, the BPD has a PN junction of a deep n-type diffusion layer (DEEP N⁻) and a shallow p-type diffusion layer (P⁰), wherein the p-type diffusion layer (P⁰) is formed on the deep n-type diffusion layer (DEEP N⁻) by using a method such as an ion-implantation technique or the like.

One side of a gate electrode 116A of the transfer transistor (Tx) is connected to the BPD and the other side is connected to a floating diffusion region (FD), wherein the gate electrode 116A of the transfer transistor (Tx) is formed on a gate insulator 134.

In addition, one side of a gate electrode 116B of the reset transistor (Rx) is connected to the floating diffusion

region (FD) and the other is connected to a power supply voltage (VDD), wherein the gate electrode 116B of the reset transistor (Rx) is formed on the gate insulator 134.

The drive transistor (Dx) and the select transistor (Sx) have each n-type lightly doped drains (N-LDD) 118 in source/drain regions 120 by ion-implanting p-type atoms into the p-well 114, while the reset transistor (Rx) and transfer transistor (Tx) have no N-LDDs therebetween. One of the source/drain regions 120 of the select transistor (Sx) plays a role as an output. A gate electrode 116C of the drive transistor (Dx) is connected to the floating diffusion region (FD). Herein, each gate insulator 134 employs a single layer in the conventional CMOS image sensor. A reference numeral 138 which is not illustrated above is sidewall spacers.

In the logic circuit 102, there is a p-well 122 for forming an n-MOSFET (n-type metal-oxide-silicon field effect transistor) 150 and an n-well 124 for forming a p-MOSFET 152, wherein the p-well 122 and the n-well 124 are disposed side by side in the p-type epitaxial layer 112. The n-MOSFET 150 has source/drain regions 126 with N-LDDs 128 by ion-implanting p-type atoms into the p-well 122 and the p-MOSFET 152 has source/drain regions 130 with P-LDDs 132 by ion-implanting n-type atoms into the n-well 124.

The conventional CMOS image sensor 100 having the single gate insulator 134 in the pixel array 101 may be applicable to device scale beyond 0.35 μm without lowering a photosensitivity and an electrical property.

However, since the conventional CMOS image sensor 100 has the single gate insulator 134 in both the pixel array 101 and the logic circuit 102 so that it is very difficult to secure desired optical property such as photosensitivity and electrical property simultaneously, the conventional CMOS image sensor 100 can be hardly applicable to the device scale less than 0.25 μm using a deep submicron technology.

Summary of the Invention

It is, therefore, an object of the present invention to provide a complementary metal oxide semiconductor (CMOS) image sensor with enhanced optical property and electrical property by employing a double gate insulator in a pixel array and a single gate insulator in a logic circuit.

It is another object of the present invention to provide a method for manufacturing a CMOS image sensor with enhanced optical property and electrical property by employing a double gate insulator in a pixel array and a single gate insulator in a logic circuit.

In accordance with one aspect of the present invention, there is provided a complementary metal oxide semiconductor (CMOS) image sensor, including: a semiconductor substrate incorporating therein a p-type epitaxial layer formed by epitaxially growing up an upper portion of the semiconductor substrate; a pixel array formed in one predetermined location of a semiconductor substrate, having a plurality of

transistors and active areas therein; and a logic circuit formed in the other predetermined location of the semiconductor substrate having active areas and at least one transistor for processing a signal from the pixel array, wherein a gate insulator of each transistor in the pixel array is thicker than a gate insulator of the transistor in the logic circuit.

In accordance with another aspect of the present invention, there is provided a method for manufacturing a CMOS image sensor, the method including the steps of: a) preparing a semiconductor substrate incorporating therein a p-type epitaxial layer, wherein the semiconductor substrate is divided into two parts of which one part is defined as a pixel array and the other part is defined as a logic circuit, the pixel array being isolated from the logic circuit by means of a field oxide region therebetween; b) forming a first gate insulator on a top face of the p-type epitaxial layer; c) forming a mask on a top face of the first gate insulator in the pixel array; d) removing the first gate insulator in the logic circuit by using the mask; e) removing the mask in the pixel array; f) forming the second gate insulator on the top face of the first gate insulator in the pixel array and a top face of the p-type epitaxial layer in the logic circuit; g) forming a photodiode and a plurality of transistors in the pixel array and at least one transistor in the logic circuit for processing a signal from the pixel array.

Brief Description of the Drawings

The above and other objects and features of the present invention will become apparent from the following description of the preferred embodiments given in conjunction with the accompanying drawings, in which:

Fig. 1 is a cross sectional view setting forth a conventional complementary metal oxide semiconductor (CMOS) image sensor having a single gate insulator in a pixel array;

Fig. 2 is a cross sectional view setting forth a CMOS image sensor having a double gate insulator in a pixel array in accordance with a preferred embodiment of the present invention; and

Figs. 3A to 3D are cross sectional views setting forth a method for manufacturing a CMOS image sensor having a double gate insulator in a pixel array in accordance with a preferred embodiment of the present invention.

Detailed Description of the Preferred Embodiments

There are provided in Fig. 2 and Figs. 3A to 3D cross sectional views of a complementary metal oxide semiconductor (CMOS) image sensor and cross sectional views setting forth a method for the manufacture thereof in accordance with a preferred embodiment of the present invention. It should be noted that like parts appearing in Fig. 2 and Figs. 3A to 3D are represented by like reference numerals.

Referring to Fig. 2, there is provided a cross sectional view of an inventive CMOS image sensor 200 including a semiconductor substrate 210, a p-type epitaxial layer 212, a pixel array 201, a logic circuit 202 and field oxide (FOX) regions. Herein, the p-type epitaxial layer 212 is formed by epitaxially growing up an upper portion of the p-type semiconductor substrate 210. The pixel array 201 and the logic circuit 202 are isolated from each other by forming a FOX region of a shallow trench isolation (STI) therebetween. Additionally, another FOX region of the STI formed in the logic circuit isolates elements in the logic circuit from each other.

In the pixel array 201, a p-well 214 is formed in a predetermined location of the p-type epitaxial layer 212 in the pixel array 201, where a drive transistor (Dx) and a select transistor (Sx) are formed in a post fabrication process. In the other predetermined location of the p-type epitaxial layer 212 in the pixel array, there is formed a buried photodiode (BPD), where a transfer transistor (Tx) and a reset transistor (Rx) are formed by a post fabrication process. Herein, the BPD has a PN junction of a deep n-type diffusion layer (DEEP N⁻) and a shallow p-type diffusion layer (P⁰), wherein the p-type diffusion layer (P⁰) is formed on the deep n-type diffusion layer (DEEP N⁻) by using a method such as an ion-implantation technique or the like.

One side of a gate electrode 216A of the transfer transistor (Tx) is connected to the BPD and the other side is

connected to a floating diffusion region (FD), wherein the gate electrode 216A of the transfer transistor (Tx) is formed on a double gate insulator having a first and a second gate insulators 234A, 234B.

5 In addition, one side of a gate electrode 216B of the reset transistor (Rx) is connected to the floating diffusion region (FD) and the other side is connected to a power supply voltage (VDD), wherein the gate electrode 216B of the reset transistor (Rx) is also formed on the double gate insulator
10 234.

 The drive transistor (Dx) and the select transistor (Sx) have each n-type lightly doped drains (N-LDD) 218 in source/drain regions 220 by ion-implanting p-type atoms into the p-well 214, while the reset transistor (Rx) and transfer
15 transistor (Tx) have no N-LDDs therein. One of the source/drain regions 220 of the select transistor (Sx) plays a role as an output. A gate electrode 216C of the drive transistor (Dx) is connected to the floating diffusion region (FD).

20 In the inventive CMOS image sensor 200, each transistor in the pixel array 201 has a gate structure of a double gate insulator 234. In detail, the first gate insulator 234A is formed on the p-type epitaxial layer 212 and the second gate insulator 234B is formed on the first gate insulator 234A.
25 Herein, a thickness of the first gate insulator 234A is preferably in a range of about 10 Å to about 40 Å and a thickness of the second gate insulator 234B preferably ranges

from about 50 Å to about 60 Å.

In the logic circuit 202, there is a p-well 222 for forming an n-MOSFET (n-type metal-oxide-silicon field effect transistor) 250 and an n-well 224 for forming a p-MOSFET 252, wherein the p-well 222 and the n-well 224 are disposed side by side in the p-type epitaxial layer 212. The n-MOSFET 250 has source/drain regions 226 with N-LDDs 228 by ion-implanting p-type atoms into the p-well 222 and the p-MOSFET 252 has source/drain regions 230 with P-LDDs 232 by ion-implanting n-type atoms into the n-well 224.

Unlike the gate structure of each transistor in the pixel array 201, each transistor in the logic circuit 202 has a single gate insulator, i.e., the second gate insulator 234B. The thickness of the single gate insulator is in the range of about 50 Å to about 60 Å.

Referring to Figs. 3A to 3D, there are shown cross sectional views setting forth a method for manufacturing a CMOS image sensor 200 in accordance with a preferred embodiment of the present invention.

In Fig. 3A, the inventive method for manufacturing the CMOS image sensor 200 begins with preparing a p-type semiconductor substrate 210 incorporating therein a p-type epitaxial layer 212 formed by epitaxially growing up an upper portion of the semiconductor substrate 210, wherein the semiconductor substrate 210 is divided into two parts of which one is a pixel array 201 and the other is a logic circuit 202.

Thereafter, a field oxide (FOX) region is formed in a

predetermined location of the p-type epitaxial layer 212 disposed between the pixel array 201 and the logic circuit 202 by using a method such as a shallow trench isolation (STI) process or the like, for isolating the pixel array from the logic circuit. Then, a first p-well 214 is formed in the p-type epitaxial layer 212 of the pixel array 201 by using a method such as an ion-implantation process or the like. In the logic circuit 202, there is formed a second p-well 222 and an n-well 224 by using a similar method for forming the first p-well 214.

Subsequently, a first gate insulator 234A is formed on a top face of the p-type epitaxial layer 212, wherein the first gate insulator 234A can employ silicon oxide (SiO_2) by thermally oxidizing the p-type epitaxial layer 212. Herein, it is preferable to form the first gate insulator 234A with the thickness ranging from about 10 Å to about 40 Å.

In an ensuing step, referring to Fig. 3B, a mask layer, e.g., a photosensitive film, is formed on a top face of the first gate insulator 234A and is patterned into a predetermined configuration through a light exposure and a development processes, thereby forming a mask 235 formed only on the top face of the first gate insulator 234A in the p-type epitaxial layer 212 of the pixel array 201. Next, the first gate insulator 234A in the logic circuit 202 is wet-etched by using the mask 235 as an etch mask, whereby the first gate insulator 234A remains only on the top face of the p-type epitaxial layer 212 of the pixel array 201. Herein, a wet-

etching process is carried out by using hydrofluoric acid (HF), buffered oxide etchant (BOE) or the like.

In a next step, referring to Fig. 3C, the mask 235 is removed by means of a predetermined etching process such as a dry etching process making use of an oxygen (O_2) plasma, a wet etching process making use of a sulfuric acid (H_2SO_4), an etching process making use of a thinner or the like. Thereafter, a second gate insulator 234B is formed on the first gate insulator 234A and the p-type epitaxial layer 212 of the logic circuit 202. Herein, it is preferable to form the second gate insulator 234B with the thickness ranging from about 50 Å to about 60 Å. In the result, each transistor in the pixel array 201 has a thick double gate insulator 234 while each transistor in the logic circuit 202 has a single layer of the second gate insulator 234B.

Finally, referring to Fig. 3D, a buried photodiode (BPD), a transfer transistor (Tx), a reset transistor (Rx), a drive transistor (Dx) and a select transistor (Sx) are formed in the pixel array 201. In addition, an n-MOSFET 250 and a p-MOSFET 252 are formed in the logic circuit 202. Therefore, an inventive CMOS image sensor 200 is achieved. Herein, the processes for fabricating above transistors and MOSFETs are well-known to those skilled in the art, so further explanation will be abbreviated in the present invention.

As aforementioned already, the inventive CMOS image sensor 200 employs the double gate insulator 234 in the pixel array 201 compared with the conventional CMOS image sensor 100

employing a single gate insulator therein. Therefore, the inventive CMOS image sensor 200 has an advantage that it is possible to apply high operating voltage ranging from about 2.5 V to 3.3 V so as to secure sufficient saturated charges due to the thick double gate insulator 234 in the pixel array 201. In addition, it is also possible to secure an appropriate dynamic range because of the sufficient saturated charges.

Furthermore, it is possible to reduce the capacitance of the floating diffusion region (FD) by reducing the capacitance of the gate insulator 234 of the drive transistor (Dx) which is connected to the floating diffusion region (FD). In addition, an increase of an electron-voltage conversion gain results in improving a photosensitivity of the CMOS image sensor 200.

Meanwhile, there is employed a single gate insulator, i.e., the second gate insulator 234B, in the logic circuit 202 so that it is possible to apply low operating voltage less than 1.8 V, to thereby reducing power dissipation. Accordingly, the inventive CMOS image sensor 200 can be applicable to a portable manufactures such as a mobile phone, a digital camera or the like which requires high speed and high efficiency property.

While the present invention has been described with respect to the particular embodiments, it will be apparent to those skilled in the art that various changes and modifications may be made without departing from the scope of

the invention as defined in the following claims.